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VARIABILITY AND DYNAMICS OF THE OUTER ATMOSPHERIC LAYERS IN THE QUIET SOLAR NETWORK

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Abstract. A detailed study of the temporal evolution of the chromospheric He I 584.33 Å and the transition region O V 629.73 Å emission line intensities of quiet supergranular network of the Sun near disk center observed with Coronal Diagnostic Spectrometer (CDS) is presented. A wavelet analysis of the 1729 s (28.8 min) long temporal series was performed in order to derive the duration as well as periods of the chromospheric and the transition region oscillations. The He I line intensities show significant power for periods around 300 s (3.3 mHz), which is relevant only in the second half of the observing sequence (between 800 – 1700 s). The temporal evolution corresponding to the O V line intensities shows strong power around period of 400 s (2.5 mHz), which is significant during the whole observing sequence as well as the oscillation of lower power for periods of around 250 s (4.0 mHz), which is present only in the middle of the observing sequence (between 700 – 1300 s).

Key words: Sun - chromosphere - transition region - oscillations

1. Introduction

Previous analyses to detect periodical phenomena were based on Fourier transformation techniques and could only provide information about periods of oscillations but it could not provide any information on eventual temporal variations of them (Bocchialini et al., 1994; Doyle et al., 1998). This diagnostic can be improved with the use of the wavelet transformation which is now used in many fields of physics, e.g. in geophysics (Torrence & Compo, 1998) and in astrophysics (Rybák & Dorotovič, 2002). The localised (in time) nature of the wavelet transform allows us to study also the duration of any statistically significant oscillation. It was well known that the chromosphere and the transition region lines show intensity power in the 250 s to 500 s (2 mHz to 4 mHz) range (Doyle et al., 1998) but the fact that the network oscillations are bursty and intermittent was revealed only after using the wavelet transformation technique (Hansteen et al., 2000; Banerjee et al., 2001). These oscillations are considered to be due to waves, which are produced in short bursts with coherence times of about 10 min to 20 min. In this contribution we present the results obtained from the wavelet analysis of the temporal variations of the chromospheric He I and the transition region O V line intensities measured by SOHO/CDS instrument in order to study properties of oscillations in/above the supergranular network of the Sun.

2. Observations and data reduction

The dataset, analyzed in this contribution, was obtained by the normal incidence part (NIS) of CDS (Harrison et al., 1995) on 14 May 1998 between 23:25 UT and 23:53 UT as a part of the joint observing programme JOP 78[1] (Kučera et al., 1999). A quiet solar region near disk center was observed in the chromospheric spectral line He I 584.33 Å ($\log T = 4.5$) and in the transition region spectral line O V 629.73 Å ($\log T = 5.4$) (Mazzotta et al., 1998; Young et al., 2003). A 1729 s ($\sim$28.8 min) long dataset of 190 spectral images with exposure time 5 s and with a cadence of 9.1 s was obtained using the 2" wide slit (oriented in the north – south direction) in sit-and-stare mode. Therefore the slit has rastered an area almost 4.4" wide in the east – west direction during the observations. Before analysis the data were corrected for the most obvious instrumental features of the CDS/NIS detector (i.e spectrum rotation and tilt, micro-channel plate burn-in, CCD flatfield) using several routines[2] of the SolarSoft software package (Freeland & Handy, 1998). The Solar Software is based on the Interactive Data Language (IDL)

[1] JOP 78 proposal: www.astro.sk/~choc/jop078_prop/

[2] More details: http://solg2.bnsc.rl.ac.uk/software/uguide/uguide.shtml

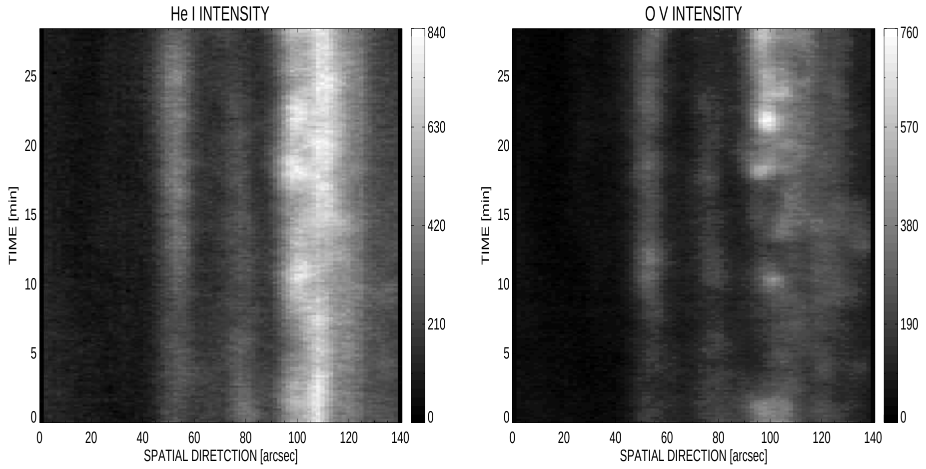

Figure 1: 2D space-time maps of the He I and the O V line intensities. The studied area, so-called typical network, is shown in the area between 111" and 116". The intensity values are given in $\mathrm{erg\,cm^{-2}s^{-1}sr^{-1}\mathring{A}^{-1}}$. The horizontal axis describes spatial direction and the vertical axis describes time. The solar rotation was not compensated, so the vertical axis presents the spatial extent of the observed solar features as well.

software.[3] The data were then converted from counts into absolute physical units. A single Gaussian profile with a linear background was then fitted to each spectral profile using the relative weights of the data (Poisson statistics[4]). This was accomplished using the standard routine CFIT[5] which is based on the Levenberg-Marquardt method of minimalization of the least squares (Press et al., 1986). Finally, the line intensities and the Doppler shifts were determined as our primary data and their square root errors were calculated. The wavelength scales were adjusted using the overall redshift of the transition region spectral lines (Peter & Judge, 1999) and the laboratory wavelengths of the He I and the O V lines (Macpherson & Jordan, 1999). Only primary data estimated with a fit uncertainity χ^2 lower than 10 $\mathrm{erg^2cm^{-4}s^{-2}sr^{-2}\mathring{A}^{-2}}$ were used for the analysis. The resulted time-space maps of the He I and the O V line intensities are displayed in Fig. 1.

[3]More details: www.rsinc.com/idl
[4]More details: http://orpheus.nascom.nasa.gov/cds/swnote/cds_swnote_49.ps
[5]More details: http://orpheus.nascom.nasa.gov/cds/swnote/cds_swnote_47.ps

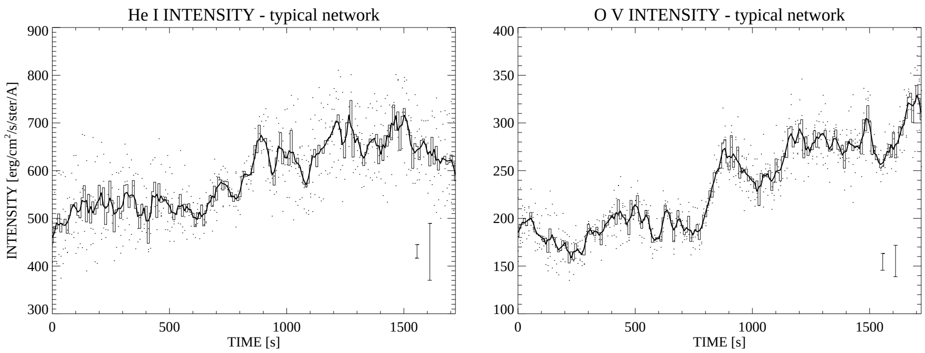

Figure 2: Temporal variations of the He I (left) and the O V (right) line intensities in the typical network. The dots show primary data, histograms display the averaged temporal variations of the primary data, and the thick lines show the smoothed variations of the averaged data. The typical square root errors of the primary data (derived from the fitting) are $\pm\,14.2$ erg cm^{-2}s^{-1}sr^{-1}Å^{-1} for the He I line and $\pm\,8.8$ erg cm^{-2}s^{-1}sr^{-1}Å^{-1} for the O V line (left error bars), respectively. The mean standard deviations of the primary data from the displayed averaged temporal variations are $\pm\,59.6$ erg cm^{-2}s^{-1}sr^{-1}Å^{-1} for the He I line and $\pm\,16.5$ erg cm^{-2}s^{-1}sr^{-1}Å^{-1} for the O V line (right error bars), respectively.

3. Results and discussion

The part of the supergranular network under study is visible in the Fig. 1 between 111" and 116". This area explicitly excluded the explosive event visible in the O V spectral line (Gömöry et al., 2003) and we named it as the "typical network". The averaged temporal variations of the He I and the O V line intensities (Fig. 2) were created as spatial average over four primary data (∼7") from the selected pixels along the slit in each exposure. The standard deviations of the primary data from the averaged values were also calculated. Each averaged variation was finally smoothed using the running mean of five points.

The wavelet analysis of the temporal variations of the He I and the O V line intensities was performed in order to determine periods and the duration of possible oscillations. The Morlet wavelet (Grossman & Morlet, 1984), as analyzing function, and the value of the wavenumber ω equal to 6 (high temporal resolution) were used for the computation of the continuous wavelet transform which was performed using program provided by Torrence and Compo.[6] As significance test, confidence level at 99% was

[6] More details: http://paos.colorado.edu/research/wavelets

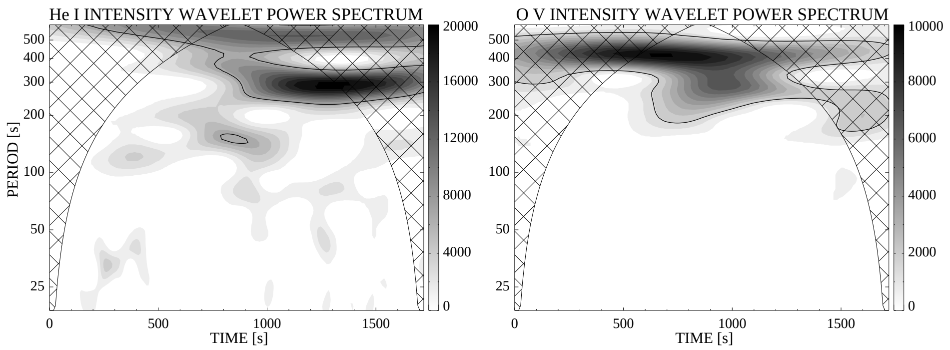

Figure 3: Wavelet power spectrum plots corresponding to the temporal variations of the He I (left) and O V line intensities. The darker regions show locations of the most likely periods in the time series. Cross-hatched regions, on either side of the spectrum, indicate the "cone of influence", i.e. areas where the edge effects become important.

calculated using a white noise background spectrum. The main advantages as like as disadvantages of the wavelet analysis were studied in details by De Moortel et al. (2004).

The resulting wavelet power spectrum plots are displayed in Fig. 3. The darker contour regions in these plots indicate the locations of the highest power, i.e. the location of the most probable periods in the time series. Note that since the solar surface rotation was not compensated during the measurements, we are not able to say anything about periods above 500 s (2.0 mHz). The wavelet analysis of the He I line intensities (Fig. 3, left panel) revealed a significant oscillation signal with a period around 300 s (3.3 mHz) in the time interval from 800 s to 1700 s (i.e. 15 min). In case of the O V line intensities the wavelet power spectrum (Fig. 3, right panel) shows strong power for periods of around 400 s (2.5 mHz). This period is relevant in the whole time interval of the observing sequence. Note that the wavelet power spectrum of the O V line intensities shows also lower power around period of 250 s (4 mHz) in the times from 700 s to 1300 s (i.e. 10 min). No considerable power was found for the He I and the O V line intensities with periods below 200 s (5 mHz).

Banerjee et al. (2001) reported oscillations in the two lower chromospheric lines (N I 1319 Å and C II 1335 Å) detected in the supergranular network. They revealed that the intensities of the N I line show maximum power around 270 s (3.7 mHz). They also remitted on the intermittent nature of these oscillations which typical life times are from 10 min to 15 min. For the C II line intensities they found considerable power with a peak around 384 s (2.6 mHz), with a lifetime of the order of 20 min. The results obtained for the N I line intensities are in good agreement with our findings for the chromospheric spectral line He I. In case of the O V line intensities Banerjee et al. (2001) found strong power in the range from 250 s to 666 s (1.5 mHz to 4.0 mHz), with the strongest peaks at 285 s (3.5 mHz) and 588 s (1.7 mHz). This is confirmed by our results obtained from the wavelet analysis of the O V line intensities.

4. Conclusion

A wavelet analysis of the temporal evolution of the chromospheric He I and the transition region O V line intensities was performed. The strongest power around periods of 300 s and 400 s was observed for the He I and the O V line intensities, respectively. The intermittent nature of these oscillations was also shown. Our results were compared with the previous work of Banerjee et al. (2001) and good agreement was found.

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